FORM PTO-1390 (Modified) (REV 11-2000) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

JC20 Rec'd PCT/PTO 28 MAR 2002

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER	46955.8
U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR	New Application 10/089535
INTERNATIONAL APPLICATION NO.	PCT/EP00/09345
INTERNATIONAL FILING DATE	September 25, 2000
PRIORITY DATE CLAIMED	October 1, 1999

TITLE OF INVENTION

Method And Device For Measuring Bulk Material Flows

APPLICANT(S) FOR DO/EO/US

Ralf Nagel and Klaus Dybeck

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☐ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include itens (5), (6), (9) and (24) indicated below.
4. ☐ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
   - a. ☒ is attached hereto (required only if not communicated by the International Bureau).
   - b. ☐ has been communicated by the International Bureau.
   - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   - a. ☒ is attached hereto.
   - b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
   - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
   - b. ☐ have been communicated by the International Bureau.
   - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   - d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).
11. ☐ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☒ A copy of the International Search Report (PCT/ISA/210).

Items 13 to 20 below concern document(s) or information included:

13. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☐ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
20. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
21. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
22. ☒ Certificate of Mailing by Express Mail
23. ☐ Other items or information:

PCTUS1/REV03

JC13 Rec'd PCT/PTO 28 MAR 2002

U.S. APPLICATION NO (IF KNOWN, SEE 37 CFR	INTERNATIONAL APPLICATION NO	ATTORNEY'S DOCKET NUMBER
New Application 10/089535	PCT/EP00/09345	46955.8

24. The following fees are submitted:.

BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :

		CALCULATIONS	PTO USE ONLY
☐ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO	**$1040.00**		
☒ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO	**$890.00**		
☐ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO	**$740.00**		
☐ International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4)	**$710.00**		
☐ International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4)	**$100.00**		
ENTER APPROPRIATE BASIC FEE AMOUNT =		**$890.00**	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).		**$0.00**	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	20 - 20 =	0	x $18 00	**$0.00**	
Independent claims	3 - 3 =	0	x $84 00	**$0.00**	
Multiple Dependent Claims **(check if applicable).**			☐	**$0.00**	
TOTAL OF ABOVE CALCULATIONS =				**$890.00**	
☒ Applicant claims small entity status. See 37 CFR 1.27). The fees indicated above are reduced by 1/2				**$445.00**	
SUBTOTAL =				**$445.00**	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)). +				**$0.00**	
TOTAL NATIONAL FEE =				**$445.00**	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) **(check if applicable).** ☐				**$0.00**	
TOTAL FEES ENCLOSED =				**$445.00**	
				Amount to be: refunded	$
				charged	$

a. ☒ A check in the amount of **$445.00** to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. ______________ in the amount of ______________ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☐ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. ______________ A duplicate copy of this sheet is enclosed.

d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

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SIGNATURE

Matthew P. McWilliams
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46,922
REGISTRATION NUMBER

March 28, 2002
DATE

10089537 .072402

DT05 Rec'd PCT/PTO 24 JUL 2002

CERTIFICATE OF MAILING BY "EXPRESS MAIL" (37 CFR 1.10) Applicant(s):			Docket No. **46955.8**
Serial No. **10/089,537**	Filing Date **March 28, 2002**	Examiner **not Yet Assigned**	Group Art Unit **Not Yet Assigned**

Invention:

Method and Device for Measuring Bulk Material Flows

I hereby certify that this **Response To Notice to File Missing Requirements, executed Declaration, and check**
(Identify type of correspondence)

is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 in an envelope addressed to: The Commissioner of Patents and Trademarks, Washington, D.C. 20231-0001 on **July 24, 2002**
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10/089537
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Attorney's Docket No. 46955.8 *Patent*

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: Ralf Nagel and Klaus Dybeck :
: Group No. : Not Yet Assigned
Serial No.: Not Yet Assigned :
: Examiner: Not Yet Assigned
Filed: herewith :

For: Method and Device for Measuring Bulk Material Flows

PRELIMINARY AMENDMENT

Box PCT
Assistant Commissioner for Patents
Washington, DC 20231

Sir:

Prior to Examination on the merits, please amend the application as follows.

IN THE CLAIMS:

Please replace claims 3 -7 and 9 -19 as follows

3. (Amended) The method according to claim 1 in which several instances of speed measurement take place and the speed of the bulk material (1) in the weighing chute (3) is derived from said several instances of speed measurement.

4. (Amended) The method according to claim 1, in which the bulk material comprises particle-shaped solid matter with a typical particle size ranging from 1 μm to 1000 mm.

5. (Amended) The method according to claim 1, in which the flow-through quantity is calculated from the measured mass and the measured speed according to $dm/dt = v \cdot M$, wherein (dm/dt) is the flow-through quantity, (M) is the measured mass and (v) is the measured speed.

6. (Amended) The method according to claim 1, in which, the speed is measured by a correlation analysis of a pair of

charge signals generated by each of the at least one pair of electrostatic induction electrodes.

7. (Amended) A device (100) for registering the flow-through quantity of bulk material (1) flowing freely through a transport line (2), the device comprising:

- a mass measuring device (10) designed for weighing the bulk material (1) present on a weighing chute (3);
- a speed measuring device (20); and
- an evaluation device (30),

characterised in that

the speed measuring device (20) comprises at least one pair of induction electrodes which is designed to provide charge signals (A1, A2) whose relative behavior over time is characteristic of the speed of the bulk material (1) in the weighing chute (3); and

the evaluation device (30) is connected with the mass measuring device (10) and the speed measuring device (20) and is designed to determine the flow-through quantity of bulk material (1) directly from the measured values obtained by the mass measuring device (10) and the speed measuring device (20).

9. (Amended) The device according to claim 7, in which the weighing chute (3) is arranged at the end of a transport line (2) or in a gap between two sections (2a, 2b) of a transport line.

10. (Amended) The device according to claim 7, in which the at least one pair of electrostatic induction electrodes, is attached to the outside of the wall of the weighing chute (3) or accommodated in the exterior wall of said weighing chute.

11. (Amended) The device according to claim 7, in which the at least one pair of electrostatic induction electrodes comprises two annular electrodes which radially encompass the weighing chute (3).

12. (Amended) The device according to claim 7, in which the at least one pair of electrostatic induction electrodes comprises electrode pieces which are arranged in the bottom region of the weighing chute (3).

13. (Amended) The device according to claim 7, in which at least one pair of electrostatic induction electrodes is attached to the transport line (2).

14. (Amended) The device according to claims 7, in which the mass measuring device (10) comprises a weighing cell (11) and a wire strain gauge (12) wherein the weighing cell (11) with the wire strain gauge (12) by means of a beam (13) is firmly attached at one end to the weighing chute (3), and at the other end to a housing (4).

15. (Amended) A weighing chute for gravimetric weighing of free-flowing bulk material (1), comprising a mass measuring device (10) and a speed measuring device (20),

characterised in that

the speed measuring device (20) comprises at least one pair of induction electrodes for registering the speed of the bulk material in the weighing chute (3).

16. (Amended) The weighing chute according to claim 15, in which the at least one pair of electrostatic induction electrodes is attached in axial direction in the middle of the weighing chute (3).

17. (Amended) The weighing chute according to claim 15, in which a first pair of electrostatic induction electrodes

is attached at a first end of the weighing chute (3), and a second pair of electrostatic induction electrodes is attached at a second end of the weighing chute (3).

18. (Amended) The weighing chute according to claim 15, in which the at least one pair of electrostatic induction electrodes is attached at the exterior wall of the weighing chute (3) or integrated in the wall of the weighing chute (3).

19. (Amended) The weighing chute according to claim 18, in which said weighing chute is of segment-like design.

REMARKS:

Claims 3 -7 and 9 -19 have been amended. The claims have been amended simply to remove multiple dependencies and to comport with U.S. practice. No new matter has been added. We look forward to favorable action on the merits at an early date.

Respectfully Submitted,

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Marked Up Copy Showing Amendments

3. (Amended) The method according to claim 1 [or 2] in which [several pairs (21, 22) of electrostatic induction electrodes are provided and through their use,] several instances of speed measurement take place and the speed of the bulk material (1) in the weighing chute (3) is derived from said several instances of speed measurement.

4. (Amended) The method according to [one of] claim[s] 1 [to 3], in which the bulk material comprises particle-shaped solid matter with a typical particle size ranging from 1 μm to 1000 mm.

5. (Amended) The method according to [one of] claim[s] 1 [to 4], in which the flow-through quantity [(dm/dt)] is calculated from the measured mass [(M)] and the measured speed [(v)] according to $dm/dt = v \cdot M$, wherein (dm/dt) is the flow-through quantity, (M) is the measured mass and (v) is the measured speed.

6. (Amended) The method according to [one of] claim[s] 1 [to 5], in which, [for measuring] the speed is measured by[,] a correlation analysis of [the] a pair of charge signals generated by each of the at least one pair of electrostatic induction electrodes[of each pair (21, 22) of electrostatic induction electrodes, takes place].

7. (Amended) A device (100) for registering the flow-through quantity of bulk material (1) flowing freely through a transport line (2), the device comprising:

- a mass measuring device (10) designed for weighing the bulk material (1) present on a weighing chute (3);
- a speed measuring device (20); and
- an evaluation device (30),

characterised in that

the speed measuring device (20) comprises at least one pair [(21, 22)] of induction electrodes which is designed to provide charge signals (A1, A2) whose relative [behaviour] behavior over time is characteristic of the speed of the bulk material (1) in the weighing chute (3); and

the evaluation device (30) is connected with the mass measuring device (10) and the speed measuring device (20) and is designed to determine the flow-through quantity of bulk material (1) directly from the measured values obtained by the mass measuring device (10) and the speed measuring device[s] ([10,]20).

9. (Amended) The device according to claim 7[or 8], in which the weighing chute (3) is arranged at the end of a transport line (2) or in a gap between two sections (2a, 2b) of [the] a transport line.

10. (Amended) The device according to [one of] claim[s] 7[to 9], in which the at least one pair [(21, 22)] of electrostatic induction electrodes [of which there is at least one], is attached to the outside of the wall of the weighing chute (3) or accommodated in the exterior wall of said weighing chute.

11. (Amended) The device according to [one of] claim[s] 7[to 10], in which [each] the at least one pair [(21, 22)] of electrostatic induction electrodes comprises two annular electrodes which radially encompass the weighing chute (3).

12. (Amended) The device according to [one of] claim[s] 7[to 10], in which [each] the at least one pair [(21, 22)] of electrostatic induction electrodes comprises electrode

pieces which are arranged in the bottom region of the weighing chute (3).

13. (Amended) The device according to [one of] claim[s] 7[to 9], in which at least one pair [(21, 22)] of electrostatic induction electrodes is attached to the transport line (2).

14. (Amended) The device according to [one of] claims 7[to 13], in which the mass measuring device (10) comprises a weighing cell (11) and a wire strain gauge (12) wherein the weighing cell (11) with the wire strain gauge (12) by means of a beam (13) is firmly attached at one end to the weighing chute (3), and at the other end to a housing (4).

15. (Amended) A weighing chute for gravimetric weighing of free-flowing bulk material (1), comprising a mass measuring device (10) and a speed measuring device (20),

characterised in that

the speed measuring device (20) comprises at least one pair [(21, 22)] of induction electrodes for registering the speed of the bulk material in the weighing chute (3).

16. (Amended) The weighing chute according to claim 15, in which [a] the at least one pair [(21)] of electrostatic induction electrodes is attached in axial direction in the middle of the weighing chute (3).

17. (Amended) The weighing chute according to claim 15, in which [two pairs (21, 22)] a first pair of electrostatic induction electrodes [are] is attached at a first end [the ends] of the weighing chute (3), and a second pair of electrostatic induction electrodes is attached at a second end of the weighing chute (3).

18. (Amended) The weighing chute according to [one of] claim[s] 15[to 17], in which the at least one pair[s] of electrostatic induction electrodes [are] is attached at the exterior wall of the weighing chute (3) or integrated in the wall of the weighing chute (3).

19. (Amended) The weighing chute according to claim 18, in which said weighing chute is of segment-like design.

(12) NACH DEM VERTRAG ÜBER DIE INTERNATIONALE ZUSAMMENARBEIT AUF DEM GEBIET DES PATENTWESENS (PCT) VERÖFFENTLICHTE INTERNATIONALE ANMELDUNG

(19) Weltorganisation für geistiges Eigentum
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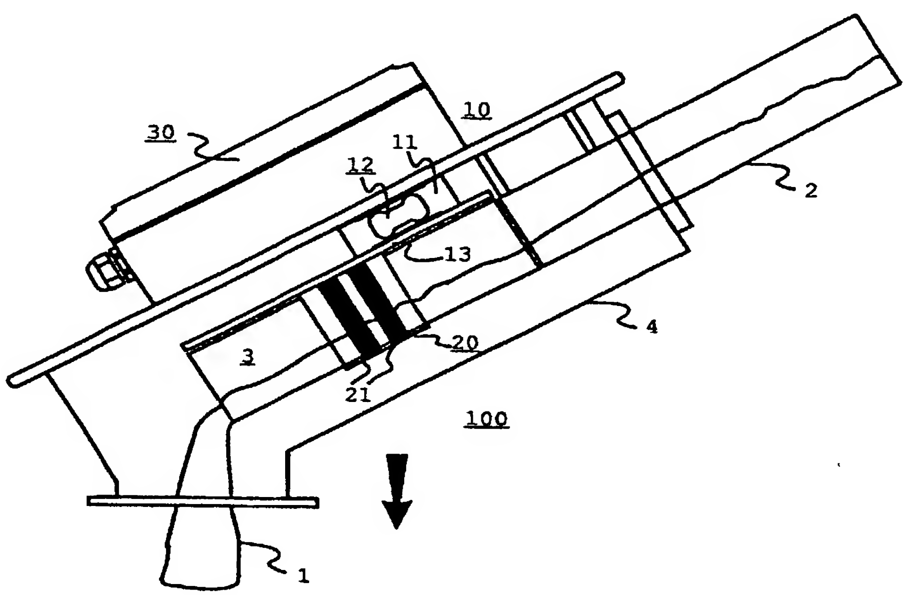
Veröffentlicht:
— *Mit internationalem Recherchenbericht.*

[Fortsetzung auf der nächsten Seite]

(54) Title: METHOD AND DEVICE FOR MEASURING STREAMS OF BULK MATERIALS

(54) Bezeichnung: VERFAHREN UND VORRICHTUNG ZUM MESSEN VON SCHÜTTGUTSTRÖMEN



(57) Abstract: The invention relates to a method and a device for detecting the flow quantity of free-flowing bulk materials (1) through a transport line (2). According to said method, a speed measurement and a gravimetric measurement of mass are performed using a weighing chute (3). The speed measurement and the measurement of mass take place simultaneously for the bulk materials which are currently on the weighing chute, by means of at least one pair of induction electrodes (21, 22) and the flow quantity is determined directly without calibration from the speed and the mass of the bulk materials (1) flowing on the weighing chute (3).

[Fortsetzung auf der nächsten Seite]

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Method and device for measuring bulk material flows

The invention relates to a method for measuring bulk material flows by simultaneous measurement of speed and mass. The invention in particular relates to a process for continuous registration of the flow-through quantity (mass flow rate) of free-flowing bulk material such as for example granules or powderised solid matter during conveyance of bulk material such as for example a process for registering the delivery quantity of material from a reservoir or loading of a bulk material carrier. The invention also relates to a device for implementing these methods.

It is known to register bulk material flows by using deflectors or measuring chutes (see for example DE-OS 29 50 925). The material to be measured impacts on a plate arranged so as to be inclined in relation to the direction in which the material drops. The mass throughput is calculated by multiplying the force measured at the deflector by a calibration factor. This method is disadvantageous due to its relatively large measurement inaccuracies and due to the necessary calibration. Measurement inaccuracies result in particular during fluctuations of the bulk material characteristics, for example in relation to the size, shape, weight and hardness of the grains as well as their impact behaviour etc.

In order to avoid such measurement inaccuracies, EP 0 372 037 describes a technique wherein the material is led down an inclined chute and from it onto a deflector wheel or a running wheel. The chute comprises a load transformer for registering the bulk material mass per length of the chute. The speed of the bulk material (travel per unit of time) is measured by means of the deflector wheel at the end of the chute, said deflector wheel rotating as a result of the moving material. The use of a deflector wheel is disadvantageous because it is a mechanically operated

element which requires additional maintenance work. In addition, caking of material on the running wheel can lead to incorrect measurement results. Evaluation of measurement results is based on the assumption of a constant speed on the chute, with the speed being measured only at the end of the chute. However, this does not take into account the fact that a change in speed occurs on the chute as a result of acceleration of the material on the chute. Again, this problem could only be compensated for by additional calibration.

From DE PS 44 06 046 a method for measuring a powder mass flow without the use of mechanically movable elements is known. In this method, a powder-gas mixture is fed along a conveyor line comprising a speed measuring device and a mass measuring device. The speed measuring device is based on the electrostatic induction method which is known per se from the publications of J.B. Gajewski et al in "Material Science", vol. 16, pp. 113 ff., and in "Electrostatics 1991 (editor B.C. O'Neill, Inst. Phys. Press, Bristol, pp. 159 ff.) and of J.V. Candy in "Signal Processing. A model approach" (McGraw Hill, New York 1988). As they are moved through the conveyor line, the powder particles are electrically charged. Two annular electrodes are attached to the conveyor line so as to be spaced apart from each other, with the charged powder particles moving through the conveyor line inducing mirror charges in said annular electrodes, it being possible to register said mirror charges as an electrical measurement signal. Evaluating correlations between the measurement signals of the annular electrodes makes it possible to draw conclusions about the speed of the powder particles.

The mass measuring device used in DE PS 44 06 046 is designed for measuring the powder mass per unit of volume in a section of the conveyor line and is based on substance flow metering using a microwave resonator.

This technique is associated with a disadvantage in that the mass measuring device allows only relative mass determination. In order to register the powder mass flow, the measured speed, the measured powder mass per unit of volume, and the dimensions of the conveyor line must be calculated, taking into account additional calibration. Determination of the mass using microwaves is associated with further disadvantages. Mass determination cannot take place in the same sector of the conveyor line as does speed measurement because the latter would be disturbed by the operation of the microwave resonator. Furthermore, measurement by means of microwaves depends to an extreme degree on extraneous boundary conditions, such as for example on the humidity of the powder. This necessitates additional process monitoring and continual re-calibration.

Generally speaking, the necessity for calibration measurement to be carried out with all conventional techniques represents a decisive disadvantage since in practical application the registration of bulk material flows should if at all possible be universal and independent of separate measurement of the bulk material parameters such as e.g. the size, shape or weight of grains.

It is thus the object of the invention to provide an improved method for measuring bulk material flows, in particular for measuring the mass throughput of free-flowing material, said method avoiding the disadvantages of conventional techniques and in particular being able to be carried out free of any calibration. The method is also intended to provide excellent measurement accuracy and a reduction in maintenance expenditure. Moreover it is the object of the invention to provide an improved measuring device for bulk material flows, in particular improved flow-through scales for weighing bulk material flows.

This object is met by a method with the characteristics according to claim 1 and a device with the characteristics according to claim 7 or 15. Advantageous embodiments and applications of the invention are stated in the dependent claims.

The invention centres on the basic idea that with free-flowing bulk material in a transport line, both speed measurement and mass measurement be carried out simultaneously on a particular quantity of bulk material. To this effect, a weighing chute is integrated in a transport line for free-flowing bulk material, with said weighing chute being designed for gravimetric mass determination of the bulk material flowing in the respective weighing chute. Furthermore, at least one pair of electrostatic induction electrodes of a speed measuring device are installed at the weighing chute or in the transport line, with the flowing bulk material generating measurable currents of electrostatic induction charges in said electrostatic induction electrodes. The speed of the bulk material is determined from the signal behaviour over time, of the currents, by means of a correlation method.

According to the invention, a generic device for measuring the flow-through quantity of bulk materials, as for example described in EP 372 037, is to be further improved to the extent that the speed is measured at the material which is present in the weighing chute. Speed measurement takes place either directly at the bulk material quantity in the weighing chute or indirectly at bulk material quantities at a distance from the weighing chute, taking into account a speed profile in the transport line.

The invention also relates to a weighing chute which is designed for simultaneous mass measurement and speed measurement of material flowing through the weighing chute.

By means of the weighing chute, the mass of the bulk material contained along the length of the weighing chute is measured directly and absolutely in kilograms per metre. Simultaneously, speed measurement determines the speed of the bulk material in metres per second. By means of product formation, the flow-through quantity can be derived directly as a through-flowing mass per unit of time, e.g. in kilograms per hour.

The invention has the following advantages. The invention provides measurement of the flow-through quantity which in contrast to all earlier techniques is derived free of any calibration, from absolute speed measurement and mass measurement. Determination of both parameters (speed and bulk material mass) takes place simultaneously for identical bulk materials. This is a particularly surprising and advantageous result because prior to the invention it had been assumed that the two parameters would require implementation of such different measurement principles that simultaneous measurement of a particular section of the transport line would be impossible. During development of the measurement technique according to the invention, the inventors arrived at an unexpected result in that the electrostatic induction method is sufficiently sensitive for measuring free-flowing bulk materials, and at the same time sufficiently robust for practical applications. In particular it was found that even in the case of bulk materials of relatively large particle size in the mm range, particles are electrostatically charged e.g. by friction, impact or fracture and that even in the case of relatively slow bulk material speeds (e.g. in the range from 1 m/s onwards) sufficient precisely-measurable currents form in the electrostatic induction electrodes.

The measurement technique according to the invention also makes possible precise flow-through quantity measurement of irregularly flowing bulk material or even of bulk material

flows that are temporarily interrupted. The measuring device according to the invention is extremely resistant to malfunction. There are no movable components such as e.g. deflector wheels or running wheels. There is no mutual interference between mass measurement and speed measurement. The invention leads to the creation of flow-through weighing scales with new and expanded application possibilities. The weighing chute with simultaneous mass measurement and speed measurement can be installed in a transport line of any shape or form. The weighing chute itself forms part of the conveyor path, with the shape and inclination of said weighing chute being identical to those of the adjacent sections of the transport line.

With the measurement technique according to the invention, the flow-through quantity can be determined with a relative accuracy of 1 % and better. By using digital evaluation electronics, the system can carry out null-balance during pauses in conveying, for example in order to compensate for a drift in the mass measuring device.

Further advantages and details of the invention are provided in the following embodiments with reference to the drawings. The following are shown:

Fig. 1: a diagrammatic general view of the mechanical components of a device according to the invention, for flow-through measurement;

Fig. 2: an illustration of the signal reception in a method according to the invention;

Fig. 3: graphs to illustrate the currents of electrostatic induction charges and their correlation;

Fig. 4: illustrations showing the position of electrostatic induction electrodes of a device according to the invention, for flow-through measurement;

Fig. 5: illustrations for combining a weighing chute according to the invention, with a transport line; and

Fig. 6: illustrations of various cross-sections of the conveyor path.

Fig. 1 illustrates the arrangement of a device 100 according to the invention, for registering the flow-through quantity of free-flowing bulk material 1 at the end of a transport line 2. In particular, the device 100 comprises a mass measuring device 10 with a gravimetric weighing chute 3, a speed measuring device 20 with a pair 21 of electrostatic induction electrodes and an evaluation device 30 which comprises a signal correlator, a weighing amplifier and a computing device for determining the flow-through quantity. The device 100 is accommodated in or on a housing 4, shown in section view, with said housing 4, depending on the particular application, being attached so as to be stationary on a base or preferably, as illustrated, at the end of the transport line 2. The weighing chute 3 is designed and attached in the housing 4 such that it forms an extension of essentially the same shape, of the conveyor path of the transport line 2. A beam 13 is attached to the top of the weighing chute 3. Preferably, the weighing chute 3 is made from segments which are held together with the beam 13. The weighing cell 11 is firmly connected to the beam 13 at one end, and to the housing 4 at the other end. By way of a mass sensor, said weighing cell comprises a wire strain gauge 12 which, depending on the mass in the weighing chute 3 and thus depending on its deflection in the direction of the arrow, supplies a predefined sensor signal to the evaluation

device 30. Instead of the wire strain gauge 12, alternative mass sensors can be applied, eg. the use of a mechanical spring element or the principle of an oscillating string or the principle of magnetic force compensation.

The weighing chute 3 carries the pair 21 of electrostatic electrodes with two electrode rings 21a, 21b mutually spaced apart. The electrode rings 21a, 21b are integrated in the wall of the weighing chute 3, or attached to the outside of said weighing chute or accommodated in an exterior sleeve which is movable on the outside of said weighing chute 3. The annular electrodes 21a, 21b are strip-shaped metallic rings which fully encompass the weighing chute 3, said annular electrodes being for example made of copper with a thickness between 30 µm and the mm range, and with a width of approx. 2 cm. Several pairs 21 of electrostatic induction electrodes may be provided, as is explained below. It is not absolutely necessary that the electrostatic induction electrodes encompass the weighing chute 3 in an annular shape. Instead, other electrode shapes such as area-shapes or strip-shapes can be realised as long as they are suitable for adequate generation of charge signals for speed measurement.

The bulk material 1 can comprise any particle-shaped inorganic or organic material. It can for example comprise mineral aggregates or artificial materials of any particle shape (spherical shapes, fragments, rod shapes etc.). Typical particle sizes are in the range above 1 µm, preferably approximately 1 mm to 5 mm. Particle sizes can also be in the cm range and far above it.

As a result of gravitational effect, the bulk material 1 moves in the transport line 2 or in the weighing chute 3 along the respective bottom of the conveyor path. To this effect, the transport line 2 and the weighing chute 3 are inclined in relation to horizontal. Their inclination or

steepness are set depending on the application, in particular depending on the flow characteristics of the bulk material, with the inclination or steepness ranging for example from 30° to 45°. Transport of the bulk material 1 takes place without any carrier gas, with said bulk material 1 sliding along the bottom of the conveyor path.

Below, the principle of signal reception in the device 100 according to the invention is explained with reference to Figures 2 and 3. Fig. 2 diagrammatically shows the weighing chute 3 according to the invention with two electrode rings 21a, 21b. The bulk material slides in the direction of the arrow along the bottom of the weighing chute 3. The speed of the bulk material flow is determined as explained below.

The bulk material flow comprises solid matter particles which are electrostatically charged during their movement. For example, electrostatic charging occurs as a result of friction between the particles themselves, friction between particles and the wall of the transport line or as a result of fracture or impact. As the electrically charged particles pass through a metal ring or generally during any movement relative to an electrical conductor, they (electrostatically) generate a mirror charge in said metal ring. The sum of the mirror charges supplies a charge signal which can be measured as a current signal in relation to mass. Due to statistical fluctuations in the bulk material flow, over time a current signal with statistical interference results. If the electrically charged particles pass through a further metal ring or pass a further metal area, again a charge signal and over time a current signal can be measured which also displays statistical interference. In both instances, the time sequence of the current noise is similar, with a time offset Δt occurring which is linear dependent on the speed of the bulk material. Further details of the electrostatic induction principle for determining particle speeds, said

principle being known per se, are described in the publication by K. Dybeck et al. in "Conference Record of 29th Annual Meeting" IEEE Industrial Application Society, Atlanta 1994.

Figure 2 illustrates the charge signal take-off (signal A1, signal A2) from the annular electrodes 21a or 21b. The signals A1, A2 are forwarded to the correlator 31. The correlator 31 forms the cross-correlation function from the signals A1 and A2 and from this determines the time offset Δt. The time offset corresponds to the position of the maximum of the cross-correlation function. This is illustrated in further detail in Figure 3 where in the upper part the output signals A1 and A2 from the annular electrodes 21a, 21b are shown, while in the lower part the cross-correlation function CCF is shown. From the known distance l of the annular electrodes 21a, 21b and the time offset, the sought bulk material speed v is determined according to

$$v = l/\Delta t.$$

The distance l between the annular electrodes 21a, 21b is for example 30 mm.

Preferably, the correlator 31 comprises a digital signal processor whose input quantities are supplied by scanning the analog signals A1, A2. The scanning rate is selected depending on a particular application, taking into account error minimisation during correlation analysis. In order to determine the cross-correlation function, corresponding to the signals A1, A2, two data sequences are recorded with a certain number N of measurement points; the data sequences are transformed to the frequency range using an N-point FFT and subjected to convolution. The result of convolution is retro-transformed into the time domain by means of an inverse N-point FFT, from which the result shown in Figure

3 (lower graph) arises. The speed v is forwarded to the computing device 32.

The signal path for determining the speed parameter thus leads from the electrostatic induction electrodes 21a, 21b to determine the charge signals via a preamplifier (not shown) and a programmable amplifier for automatic signal adaptation (also not shown) to the correlator 31 which contains the digital signal processor and calculates the cross-correlation function and from it the speed. The programmable amplifier is used to optimise signal amplitude of the charge signals during changes in product characteristics or in mass throughput.

As an alternative, the time offset can also be determined using other signal analysis processes, such as e.g. sample evaluation or image evaluation or iteration processes.

The signal for the mass parameter (signal B) directly travels from the weighing cell 11 (see Figure 1) of the weighing chute 3 via a weighing amplifier 14 to the computing device 32.

In the computing device 32 the flow-through quantity dm/dt is calculated from the speed and the mass M measured per unit of length of the weighing chute 3, as follows:

$$dm/dt\ [kg/h] = v\ [m/sec] \cdot M\ [kg/m] \cdot 3600$$

Thus the computing device 32 supplies the flow-through quantity directly, without any additional calibration steps. The respectively calculated quantitative variable for dm/dt can be forwarded for further evaluation, to a display unit or to a system control unit as an input quantity e.g. for a conveyor.

Figure 4 illustrates various embodiments of electrode positioning at the weighing chute 3. The annular electrodes 21a, 21b, which in the alternative may also be non-circumferential electrode pieces near the lower part of the weighing chute when the latter is in the operating position, form a pair 21 of electrostatic induction electrodes. Each pair 21 of electrostatic induction electrodes is attached so as to extend around the exterior circumference of the weighing chute or so as to be embedded in the wall of said weighing chute. In the former case, the weighing chute must be made from an electrically insulating material. If electrostatic induction electrodes are bonded to or embedded in the weighing chute, this is not required. Preferably a segment-like design is selected where chute segments alternate with electrode segments.

In contrast to Figure 1, Figure 4 shows the weighing chute 3 between the intake 2a and the outlet 2b of the transport line (not otherwise shown). In the upper diagram, the pair 21 of electrostatic induction electrodes is attached in axial direction in the middle of the weighing chute 3. In a modified embodiment according to the middle diagram in Figure 4, two pairs 21, 22 of electrostatic induction electrodes, one at the beginning and one at the end of the weighing chute 3, are provided. This embodiment has an advantage in that the speed of the bulk material can be determined with increased accuracy. Since, as a result of gravitational forces, the speed of the bulk material still increases as the material flows through the weighing chute 3, two speed values can be determined using the two pairs 21, 22 of electrostatic induction electrodes, and from said two speed values, an average speed value can be determined. Further pairs of electrostatic induction electrodes may be provided in order to record speed profiles along the weighing chute and/or in order to improve speed measurement.

The bottom diagram in Figure 4 illustrates a further embodiment of the invention in which two pairs 21, 22 of electrostatic induction electrodes are arranged at the end of the intake 2a or at the beginning of the outlet 2b. From the distances between the pairs 21 or 22 of electrostatic induction electrodes and the weighing chute 3, assuming a predefined speed profile of the bulk material, the speed in the weighing chute 3 can be determined. The speed profile is for example a linear profile, i.e. the speed of the bulk material linearly increases in the direction of transport. However, the speed profile can also be more complex or it can be simpler. Depending on the material, steepness and length of the conveyor path, slowing down or, in the case of an equilibrium between friction and gravitation, a constant speed of the bulk material can occur.

The embodiment according to the bottom diagram of Fig. 4 is advantageous in relation to the simplified mechanical design of the weighing chute and the lack of wires on said weighing chute. However, an outlet is a prerequisite with this embodiment.

According to a further embodiment (not shown), a single pair of electrostatic induction electrodes could be provided outside the weighing chute, which, taking into account the distance from the weighing chute, and the assumed speed profile or a constant speed present on the conveyor path, again results in a speed value of the bulk material in the attached tote. However, this embodiment provides less accuracy.

It must be emphasised that embodiments of the invention where the pairs of electrostatic induction electrodes are outside the attached tote, also make it possible to simultaneously measure the speed and the mass in the case of identical bulk material. With free-flowing bulk material, the interpolation based on speed profiles is

sufficiently accurate to draw conclusions about the speed in the weighing chute based on speed values outside the weighing chute.

For example, a measuring device realised in practical application, for measuring granules of artificial material with an average grain size of 2 mm and a throughput of approx. 0.5 to 2 t/h, comprises the following characteristics. Its design corresponds to that shown in the upper diagram of Fig. 4. The length of the weighing chute is 200 mm; its inclination relative to horizontal is 30°; and its tube diameter is 50 mm. The granular material travels at a typical speed of approx. 1.7 m/s. At maximum throughput, the mass M in the weighing chute is approx. 65 g / 200 mm.

Figures 5 and 6 illustrate various arrangements of the weighing chute 3 in relation to the transport line 2 or the profile of the transport line 2 and the weighing chute 3. The weighing chute 3 according to the invention can be integrated in the transport line 2 (Figure 5, upper part) or it can be provided at the end of the transport line 2. In each case, the cross-sectional profile of the weighing chute exactly matches the cross-sectional profile of the transport line, with the weighing chute 3 being arranged so as not to touch the transport line. Most of the time, a gap between the weighing chute 3 and the respective adjacent parts of the transport line 2 comprises a characteristic dimension which is smaller than the typical particle size of the flowing bulk material. For example, in the case of granular bulk material with a particle size around 2 mm, the gap is 1 mm in width. With a large throughput, there is a suction-like effect in the bulk material flow which, in particular when conveying powder, prevents the gap from closing. The gap width can thus also be larger than the size of the particles conveyed.

The transport line and the weighing chute comprise a closed cross section or an open-top cross section as is illustrated in Figure 6. A tubular shape is a preferred closed cross-sectional shape. By way of open shapes, for example, a tubular segment or a rectangular shape can be formed. Further variations are possible, with a cross-sectional shape being preferred such that the bulk material is concentrated in the lowermost point in the operational position, of the conveyor path. However, the cross-sectional shape can also be triangular or formed by a combination of the above-mentioned shapes.

The weighing chute 3 can be arranged so as to be suspended or supported from below, with a suspended arrangement being preferred because the weighing cell 11 (see Figure 1) is protected against any bulk material that may issue and does not interfere with the flow of bulk material from the outlet and also because it makes it possible to maintain short low-interference cable lines for signal transmission.

The characteristics of the invention disclosed in the above description, the drawings and the claims, can be of importance both individually and in any combination, in implementing the invention in its various embodiments.

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CLAIMS

1. A method for registering the flow-through quantity of bulk material (1) flowing freely through a transport line (2), which method provides for both speed measurement and mass measurement, wherein mass measurement takes place gravimetrically using a weighing chute (3),

characterised in that

speed measurement and mass measurement take place simultaneously for bulk material which is present in the weighing chute, with the use of at least one pair (21, 22) of induction electrodes, and in that

the flow-through quantity is determined without calibration, directly from the speed and the mass of the bulk material (1) flowing on the weighing chute (3).

2. The method according to claim 1 in which mass measurement takes place with a suspended or supported weighing chute (3).

3. The method according to claim 1 or 2 in which several pairs (21, 22) of electrostatic induction electrodes are provided and through their use, several instances of speed measurement take place and the speed of the bulk material (1) in the weighing chute (3) is derived from said instances of speed measurement.

4. The method according to one of claims 1 to 3, in which the bulk material comprises particle-shaped solid matter with a typical particle size ranging from 1 μm to 1000 mm.

5. The method according to one of claims 1 to 4, in which the flow-through quantity (dm/dt) is calculated from the measured mass (M) and the measured speed (v) according to dm/dt = v · M.

6. The method according to one of claims 1 to 5, in which, for measuring the speed, a correlation analysis of the charge signals of the electrostatic induction electrodes of each pair (21, 22) of electrostatic induction electrodes, takes place.

7. A device (100) for registering the flow-through quantity of bulk material (1) flowing freely through a transport line (2), comprising:

- a mass measuring device (10) designed for weighing the bulk material (1) present on a weighing chute (3);
- a speed measuring device (20); and
- an evaluation device (30),

characterised in that

the speed measuring device (20) comprises at least one pair (21, 22) of induction electrodes which is designed to provide charge signals (A1, A2) whose relative behaviour over time is characteristic of the speed of the bulk material (1) in the weighing chute (3); and

the evaluation device (30) is connected with the mass measuring device (10) and the speed measuring device (20) and is designed to determine the flow-through quantity of bulk material (1) directly from the measured values obtained by the mass measuring and the speed measuring devices (10, 20).

8. The device according to claim 7, in which the weighing chute (3) is arranged so as to be suspended or supported from below.

9. The device according to claim 7 or 8, in which the weighing chute (3) is arranged at the end of a transport line (2) or in a gap between two sections (2a, 2b) of the transport line.

10. The device according to one of claims 7 to 9, in which the pair (21, 22) of electrostatic induction electrodes of which there is at least one, is attached to the outside of the wall of the weighing chute (3) or accommodated in the exterior wall of said weighing chute.

11. The device according to one of claims 7 to 10, in which each pair (21, 22) of electrostatic induction electrodes comprises two annular electrodes which radially encompass the weighing chute (3).

12. The device according to one of claims 7 to 10, in which each pair (21, 22) of electrostatic induction electrodes comprises electrode pieces which are arranged in the bottom region of the weighing chute (3).

13. The device according to one of claims 7 to 9, in which at least one pair (21, 22) of electrostatic induction electrodes is attached to the transport line (2).

14. The device according to one of claims 7 to 13, in which the mass measuring device (10) comprises a weighing cell (11) and a wire strain gauge (12) wherein the weighing cell (11) with the wire strain gauge (12) by means of a beam (13) is firmly attached

at one end to the weighing chute (3), and at the other end to a housing (4).

15. A weighing chute for gravimetric weighing of free-flowing bulk material (1), comprising a mass measuring device (10) and a speed measuring device (20),

characterised in that

the speed measuring device (20) comprises at least one pair (21, 22) of induction electrodes for registering the speed of the bulk material in the weighing chute (3).

16. The weighing chute according to claim 15, in which a pair (21) of electrostatic induction electrodes is attached in axial direction in the middle of the weighing chute (3).

17. The weighing chute according to claim 15, in which two pairs (21, 22) of electrostatic induction electrodes are attached at the ends of the weighing chute (3).

18. The weighing chute according to one of claims 15 to 17, in which the pairs of electrostatic induction electrodes are attached at the exterior wall of the weighing chute (3) or integrated in the wall of the weighing chute (3).

19. The weighing chute according to claim 18, which is of segment-like design.

20. The use of a method, a device, or a weighing chute according to one of the preceding claims, for registering the flow-through quantity of free-flowing bulk materials.

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ABSTRACT

For registering the flow-through quantity of bulk material (1) flowing freely through a transport line (2), with the provision of both speed measurement and gravimetric mass measurement using a weighing chute (3), speed measurement and mass measurement take place simultaneously for bulk material which is present in the weighing chute, with the use of at least one pair (21, 22) of electrostatic induction electrodes, with the flow-through quantity being determined without calibration, directly from the speed and the mass of the bulk material (1) flowing in the weighing chute (3).

(Fig. 1)

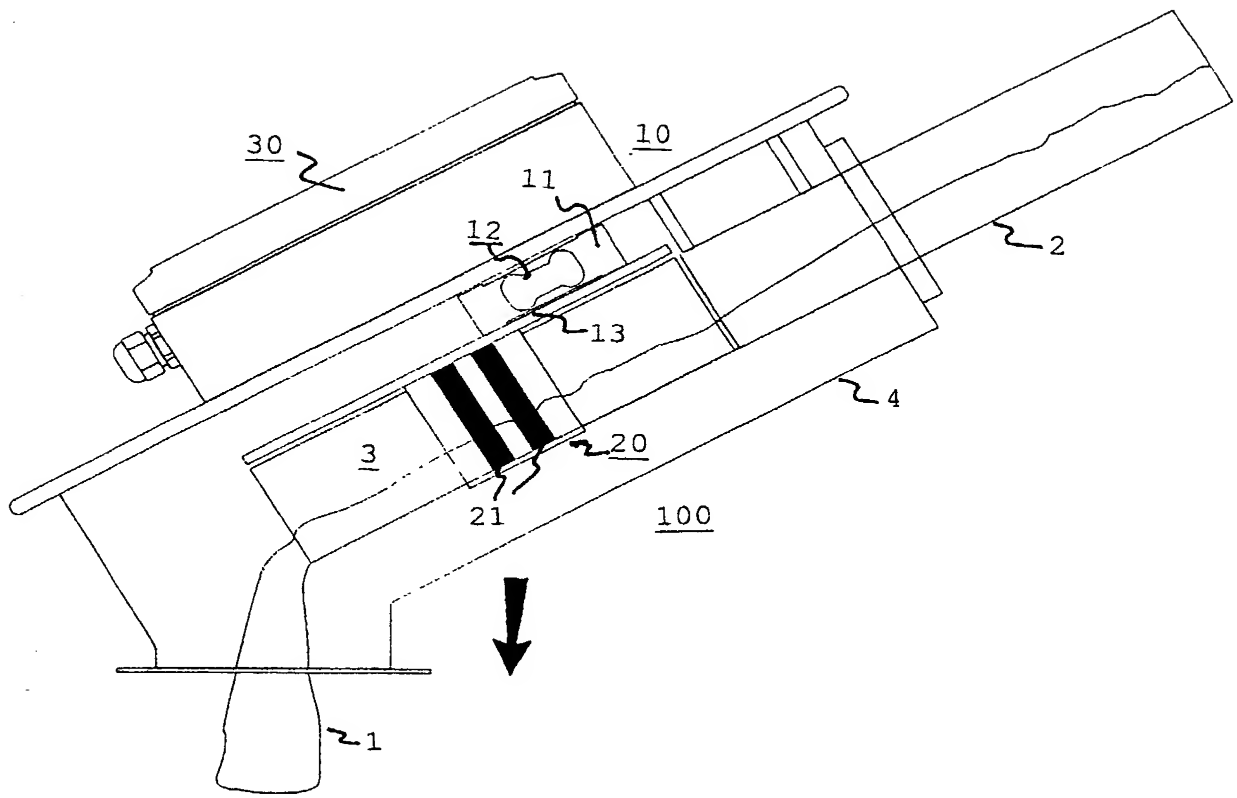

Fig. 1

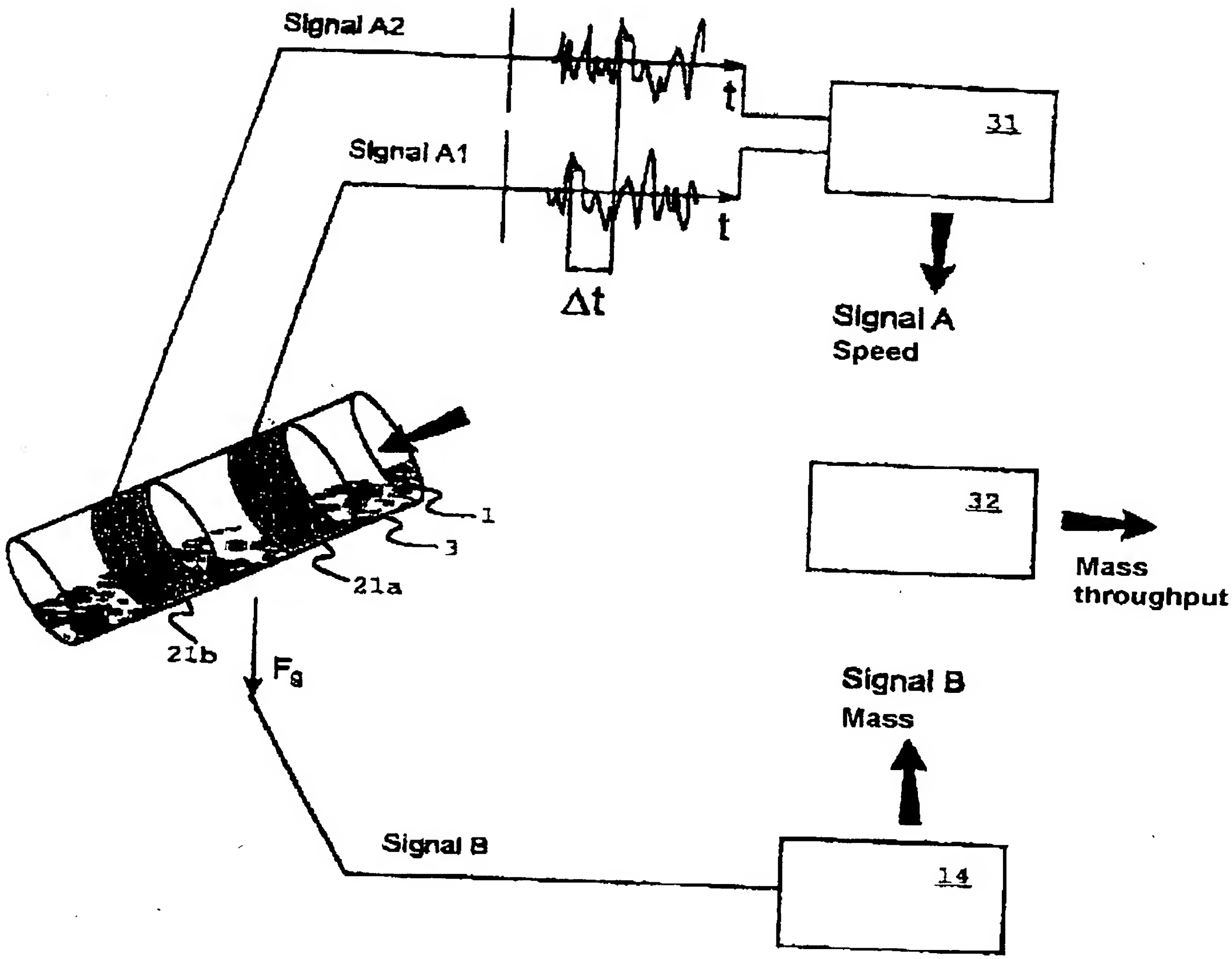
Signal A2
t
Signal A1
t
Δt
31
Signal A
Speed
1
3
21a
21b
F_g
32
Mass
throughput
Signal B
Mass
Signal B
14

Fig.2

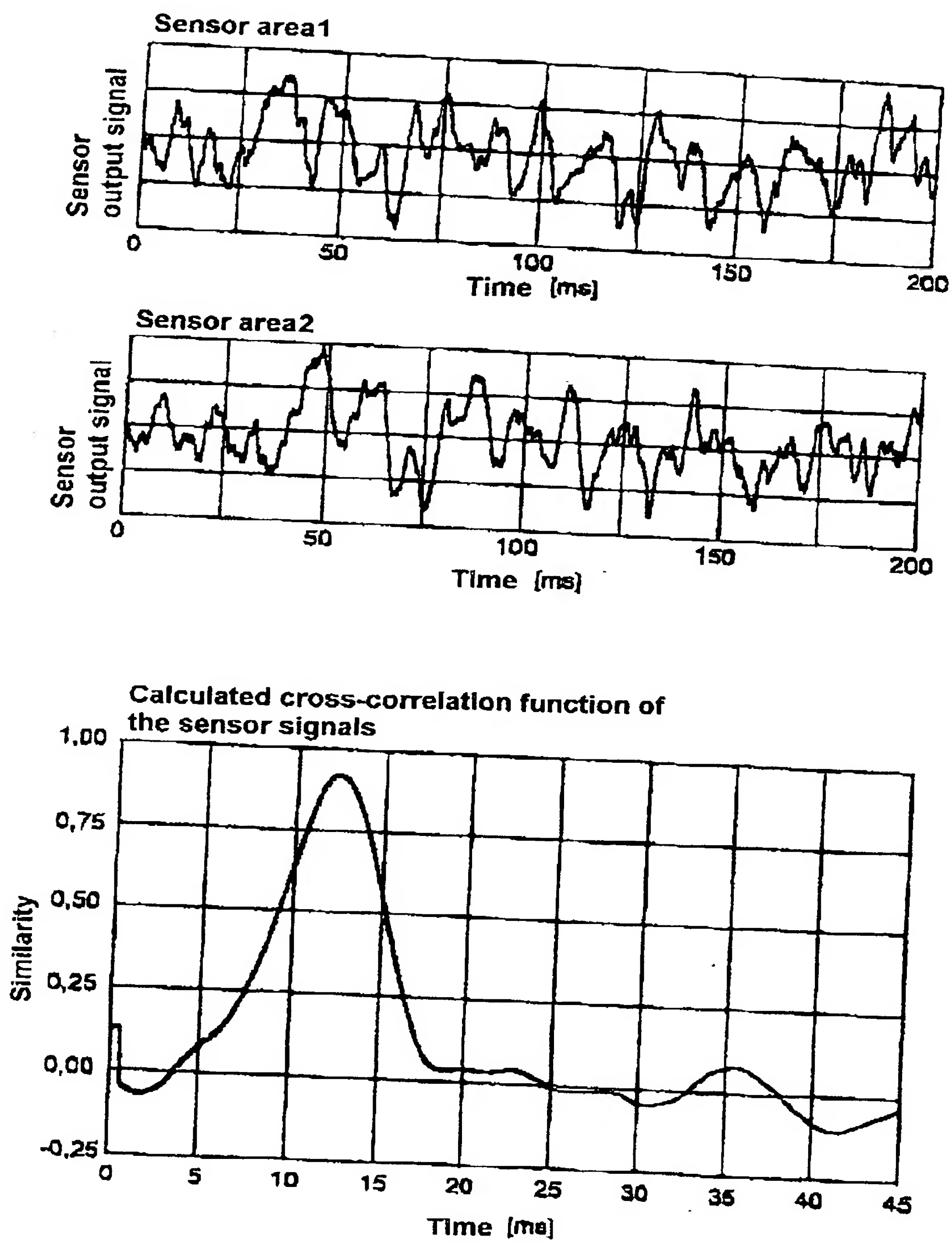
Sensor area1
Sensor output signal
0
50
100
150
200
Time [ms]
Sensor area2
Sensor output signal
0
50
100
150
200
Time [ms]
Calculated cross-correlation function of the sensor signals
1,00
0,75
0,50
0,25
0,00
-0,25
Similarity
0
5
10
15
20
25
30
35
40
45
Time [ms]

Fig.3

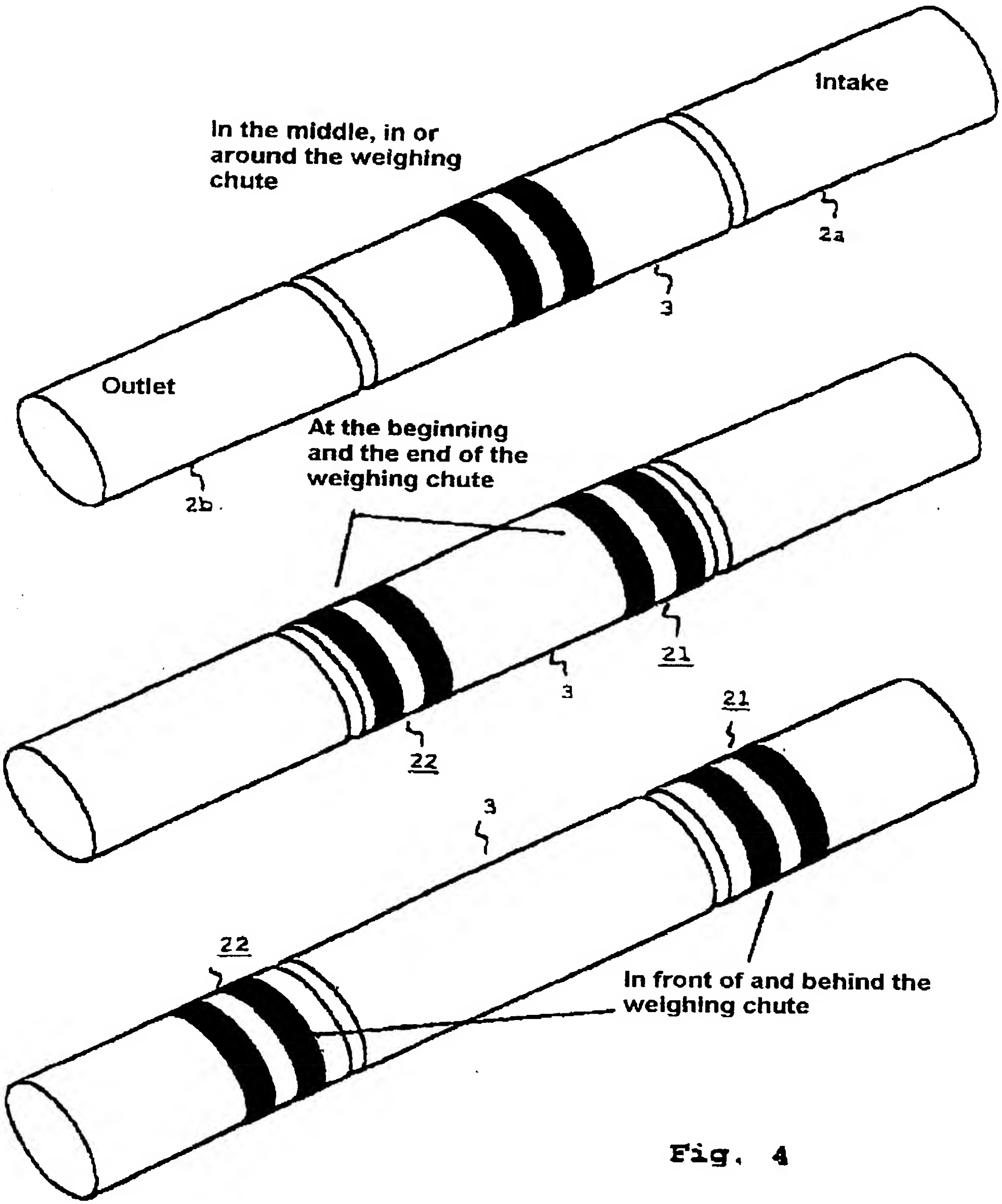
Intake
In the middle, in or around the weighing chute
2a
3
Outlet
2b
At the beginning and the end of the weighing chute
21
3
22
21
3
22
In front of and behind the weighing chute

Fig. 4

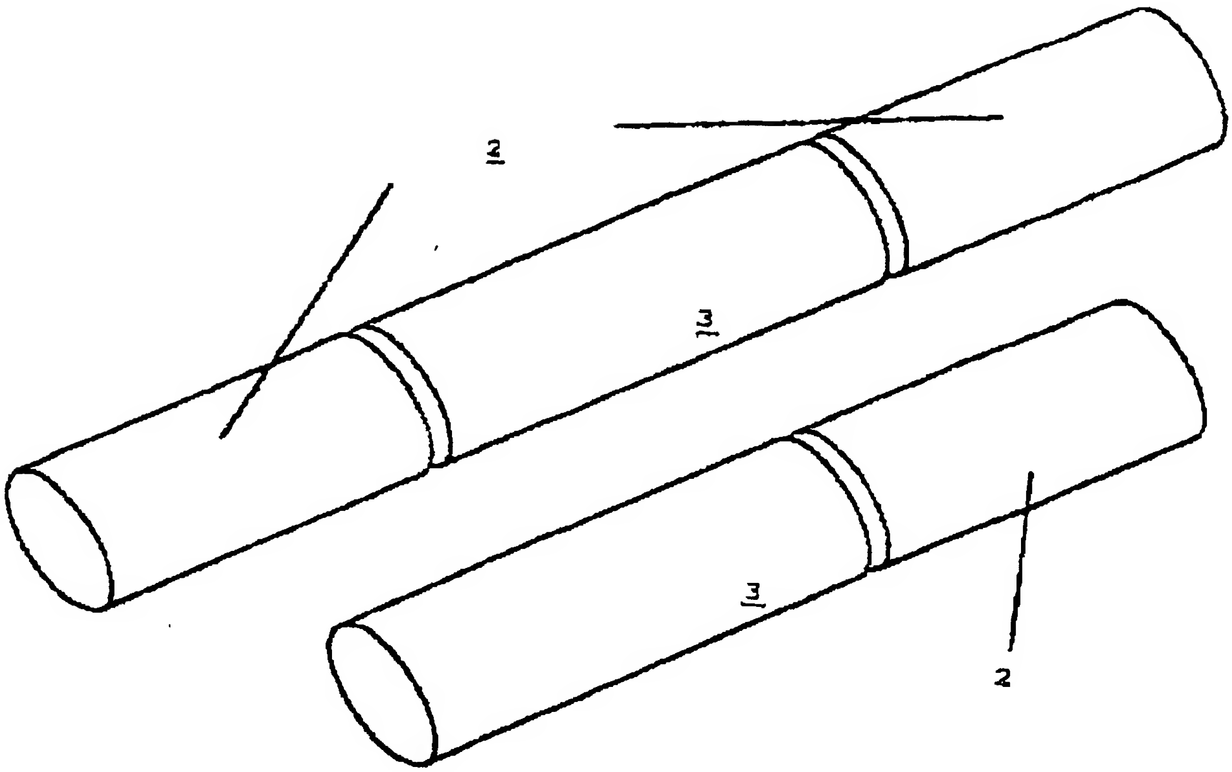

Fig. 5

Fig. 6

COMBINED DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

As a below-named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am an original, first and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled **METHOD AND DEVICE FOR MEASURING BULK MATERIALS FLOWS** the specification of which:

(check one)

☐ is attached hereto.

☒ was filed on March 28, 2002 as Application Serial Number 10/089,537

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119 of any foreign application (s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claim:

Prior Foreign Application(s)			Priority Claimed	
PCT/EP00/09345 (Number)	PCT (Country)	25/ 9 /2000 D/M/YR Filed	☒ YES	☐ NO
199 47 384.3 (Number)	Germany (Country)	01/10/1999 D/M/YR Filed	☒ YES	☐ NO
(Number)	(Country)	/ / D/M/YR Filed	☐ YES	☐ NO

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I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application (s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, § 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Serial No.)	(Filing Date)	(Status)(patented, pending, abandoned)
(Application Serial No.)	(Filing Date)	(Status)

POWER OF ATTORNEY

As a named inventor, I hereby appoint the following attorneys jointly and each of them severally, with full power of substitution, delegation, and revocation, to prosecute this application, to make alterations and amendments therein, to receive the patent, and to transact all business in the Patent and Trademark Office connected therewith:

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DECLARATION

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

SIGNATURES

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